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ABSTRACT:

PURPOSE: To prevent the movement of superconducting element wires within a conduit and at the same time maintain a path for a coolant to flow, by fixing the element wires with a thermohardening type insulating tape wound in a spiral form in the direction of the length thereof on the outer circumference of a secondary twisted wire in which a plurality of superconducting element wires are twisted.

CONSTITUTION: A superconducting element wire 11 is formed with an extremely thin multi-core superconducting wire of NbTi or Nb<SB>3</SB>Sn being surrounded with a stabilization material such as Cu, Al or the like. Three pieces of the element wires 11 are twisted to make a primary twisted wire 12, and three pieces of the primary twisted wires 12 are twisted to make a secondary twisted wire 13. A thermohardening type insulating tape is wound on the twisted wire 13 in a spiral form along in the direction of the length thereof. A plurality of the twisted wires 13, the circumference of which the insulating tape 14 is applied to, are twisted to make a subcable 15. In this case, six pieces of subcables 15 are twisted and then housed in the conduit 16. The superconducting wire is made by drawing. Thereby, the movement of the element wire 11 is restricted by the thermohardening type insulating layer 18. However, there is not present the layer 18 all over the space between the element wires 11, so that a path for a coolant to flow can be maintained.

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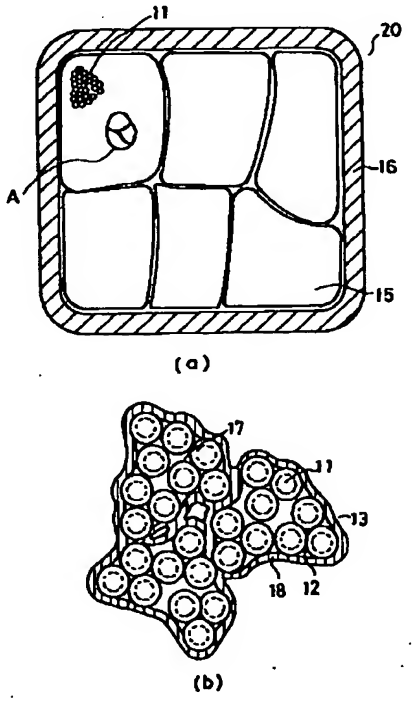
(54)【発明の名称】　超電導導体

(57)【要約】

【目的】本発明は、コンジット内の超電導素線の動きを防ぐとともに冷媒流路を確保し安定性のある冷却特性の優れた超電導導体を提供することにある。

【構成】本発明は、ＮｂＴｉまたはＮｂ$_3$Ｓｎの極細多芯線の超電導素線からなる撚線を高強度ステンレス鋼製の管内に納めて、この管内に冷媒を圧送して強制冷却するケーブル・イン・コンジット型の超電導導体において、前記撚線を形成する超電導素線を複数本撚り合せた２次撚線の外周に熱硬化型の絶縁テープを長尺方向にスパイラル状に巻回して超電導素線を互いに固定しているので、超電導素線の動きを最小限に拘束しかつ素線間の冷媒流路を確保できる。したがって、安定で冷却特性の優れた超電導導体を提供することができる。



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【特許請求の範囲】

【請求項1】　ＮｂＴｉまたはＮｂ$_3$　Ｓｎの極細多芯線の超電導素線からなる撚線を高強度ステンレス鋼製の管内に納めて、この管内に冷媒を圧送して強制冷却するケーブル・イン・コンジット型の超電導導体において、前記撚線を形成する超電導素線を複数本撚り合せた２次撚線の外周に熱硬化型の絶縁テープを長尺方向にスパイラル状に巻回して超電導素線を互いに固定したことを特徴とする超電導導体。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、超臨界ヘリウムを強制的に圧送して冷却する強制冷却型の超電導導体に関する。

【０００２】

【従来の技術】超臨界ヘリウムのような単相流，極低温流体の強制対流を利用して冷却する強制冷却型の超電導導体には、ホロー導体、ケーブル・イン・コンジット導体およびそれらを組合わせた導体などがある。ホロー導体は極細多芯超電導線を多数本集合して半田等で安定化材とともに一体化し、その中央部分に穴をあけて冷媒であるヘリウムを圧送できるように構成されている。また、ケーブル・イン・コンジット導体８は、図３に示すようにＮｂＴｉやＮｂ$_3$　Ｓｎの極細多芯超電導線１を数本ずつ多数回撚り合せて２次撚線２，３次撚線３，４次撚線４，５次撚線５とケーブル状に多重撚りし、ＳＵＳ材やインコロイ材，Ｔｉ材またはそれらの合金等からなる強固なコンジット（管）６内に納め、超電導素線以外のコンジット６内壁とで囲まれた空間７に冷媒が流れるように構成されている（米国特許第４，３３６，４２０号明細書：Ｊｕｎ．２２，１９８２，参照）。

【０００３】この種の超電導導体は、コンジット６内の超電導素線１が電磁力によってコンジット６内で動くことにより発熱し、素線温度が上昇して超電導破壊（クエンチ）することを防ぐため、超電導素線１の表面に半田を薄くコーティングし、撚線時にお互い点接触，線接触した部分で半田付け固定して動かないようにしている。また、撚線を数回束ねたケーブルに対してその外周を熱伝導特性の良好な高電気抵抗材で覆うことにより素線の動きを拘束している。さらに、コンジット６内のケーブル空間の断面積に対する冷媒流路面積の占める割合（以下ボイド率と称する）をできるだけ小さくなるように（一般には３５～４０％前後）管径をしごいて小さくしていた。

【０００４】

【発明が解決しようとする課題】上述したように、従来の超電導導体では、コンジット内の超電導素線は半田コーティングされていて超電導素線の動きは拘束されるが、超電導素線間の電気的接続のため変動磁界に対する結合損失が大きく、この内部発熱のためクエンチに至る

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ことがあるため、電気的に素線間を結合せず単に撚り合せることによってのみ固定すると、曲げ径の異なる箇所や電磁力の強大な箇所では素線が動き易くなるという欠点があった。

【０００５】そこで、従来の超電導導体では素線の動き易さを防ぐためボイド率を極力小さくしているが、導体製造時の素線の断線や水力直径が小さくなるため圧力損失が増大し、ひいては循環ポンプの損失が非常に大きくなったり、圧損による温度上昇で冷媒の温度が高くなる等の別の欠点が生じた。

【０００６】上述したような欠点を補う方法として、超電導素線の外周に半田付け固定する代りに接着剤を塗布してお互いに接着し固定したもの（特開平２－２９７８０８号公報）が提案されているが、この方法では素線同士を互いに接着する際、超電導素線間の冷媒流路が塞がってしまい、冷媒が流れなくなり著しい冷却特性の劣化を招き、ひいてはクエンチ（超電導破壊）を生じるという問題があった。

【０００７】本発明は上記問題を解決するためになされたもので、その目的はコンジット内の超電導素線の動きを防ぐとともに冷媒流路を確保し安定性のある冷却特性の優れた超電導導体を提供することにある。

【０００８】

【課題を解決するための手段】上記目的を達成するために、本発明はＮｂＴｉまたはＮｂ$_3$　Ｓｎの極細多芯線の超電導素線からなる撚線を高強度ステンレス鋼製の管内に納めて、この管内に冷媒を圧送して強制冷却するケーブル・イン・コンジット型の超電導導体において、前記撚線を形成する超電導素線を複数本撚り合せた２次撚線の外周に熱硬化型の絶縁テープを長尺方向にスパイラル状に巻回して超電導素線を互いに固定したことを特徴とする。

【０００９】

【作用】本発明の超電導導体によれば、超電導素線の動きを最小限に拘束しかつ素線間の冷媒流路を確保しているので、優れた安定性及び冷却特性が得られる。

【００１０】

【実施例】以下、本発明の実施例を図１を参照して説明する。

【００１１】図１（ａ）は本発明の一実施例の断面図であり、図１（ｂ）は同図（ａ）のＡ部の拡大図である。図１において、１１は超電導素線であり、ＮｂＴｉやＮｂ$_3$Ｓｎの極細多芯超電導線をＣｕやＡｌ等の安定化材で囲み、さらに必要に応じて電気絶縁材を挿入する。この超電導素線１１は図２に示すように３本ずつ撚られて１次撚線１２を形成し、さらに１次撚線１２は３本撚って２次撚線１３を形成する。この２次撚線１３の外周に熱硬化型の絶縁テープ１４を長尺方向に沿ってスパイラル状に巻回する。このように外周に絶縁テープ１４を施された２次撚線１３は、図３に示す従来例と同様に多数

回撚線され、サブケーブル１５を構成する。

【００１２】本実施例の場合、サブケーブル１５を６本撚線してコンジット１６に収納し、所定のボイド率までダイス引きして超電導導体２０を製作する。超電導導体２０の製作後、コイル製作の適当な過程で超電導導体２０を加熱して熱硬化型の絶縁テープ１４を硬化させ、超電導素線１１を２次撚線単位で固定する。硬化後の超電導導体２０は図１（ａ）に示すようになり、そのＡ部を拡大したものを図１（ｂ）に示す。

【００１３】硬化絶縁層１８が１次撚線１２の状態で超電導素線１１を固定しており、これにより超電導素線１１の動きを拘束している。しかし、超電導素線１１間の全てに硬化絶縁層１８がないため冷媒流路１７を確保できる。したがって、コイルを形成して通電しても超電導素線１１の動きはほとんどなく優れた安定性を有するとともに良好な冷却特性も得ることができる。

【００１４】なお、本実施例では熱硬化型の絶縁テープの巻きピッチについて特に規定しなかったが、密巻きまたはラップ巻きにすると、冷却表面積が減少したり電流の偏流、分流問題が生じるため飛ばし巻きを行なうことにより冷却表面積の減少を防ぎ、偏流、分流問題の軽減

ができる。この場合、飛ばし巻きのピッチは、３次撚線（3^3 本撚り）の撚りピッチの１／３長以下のピッチとするのがよい。また、２次撚線は２本撚り、４本撚り等複数本撚りを用いても上記実施例と同様の効果が得られる。

【００１５】

【発明の効果】以上説明したように、本発明によればコンジット内の超電導素線の動きを防ぐとともに冷媒流路を確保できるので、安定で冷却特性の優れた超電導導体を提供することができる。

【図面の簡単な説明】

【図１】同図（ａ）は本発明の一実施例の断面図、同図（ｂ）は同図（ａ）のＡ部の拡大図。

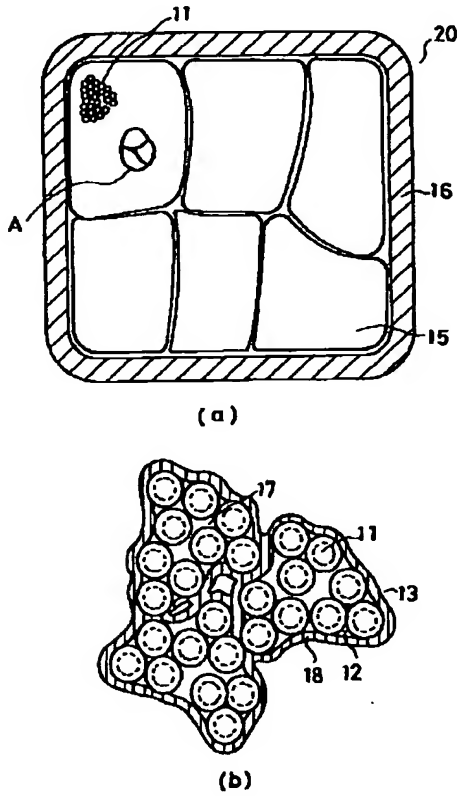
【図２】図１の２次撚線の１部の斜視図。

【図３】従来の超電導導体の製作工程を示す図。

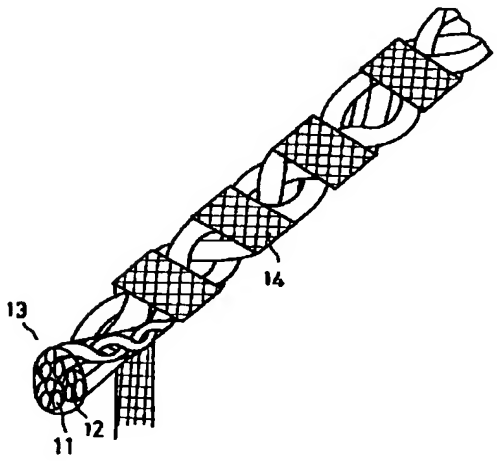
【符号の説明】

１１…超電導素線、１２…１次撚線、１３…２次撚線、１４…熱硬化型の絶縁テープ、１５…サブケーブル、１６…コンジット、１７…冷媒流路、１８…硬化絶縁層、２０…超電導導体。

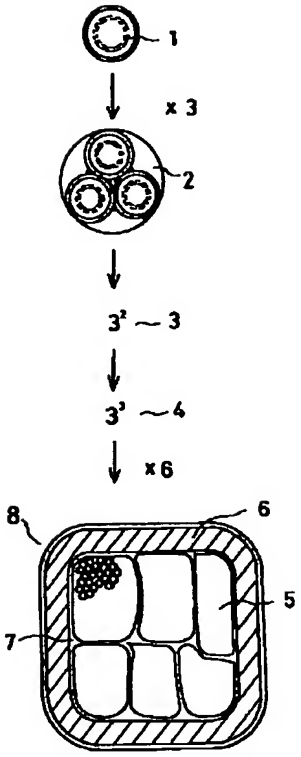
【図１】



【図２】



【図3】



PATENT ABSTRACTS OF JAPAN

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(71)Applicant : TOSHIBA CORP

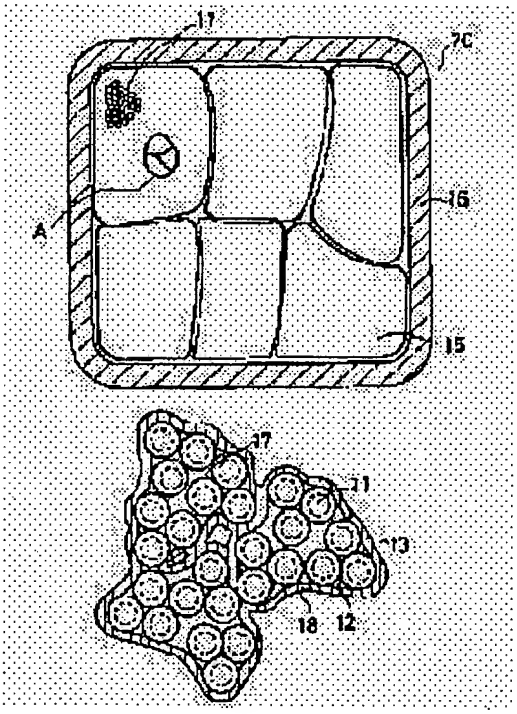
(72)Inventor : WACHI YOSHIHIRO

(54) SUPERCONDUCTOR

(57)Abstract:

PURPOSE: To prevent the movement of superconducting element wires within a conduit and at the same time maintain a path for a coolant to flow, by fixing the element wires with a thermohardening type insulating tape wound in a spiral form in the direction of the length thereof on the outer circumference of a secondary twisted wire in which a plurality of superconducting element wires are twisted.

CONSTITUTION: A superconducting element wire 11 is formed with an extremely thin multi-core superconducting wire of NbTi or Nb3Sn being surrounded with a stabilization material such as Cu, Al or the like. Three pieces of the element wires 11 are twisted to make a primary twisted wire 12, and three pieces of the primary twisted wires 12 are twisted to make a secondary twisted wire 13. A thermohardening type insulating tape is wound on the twisted wire 13 in a spiral form along in the direction of the length thereof. A plurality of the twisted wires 13, the circumference of which the insulating tape 14 is applied to, are twisted to make a subcable 15. In this case, six pieces of subcables 15 are twisted and then housed in the conduit 16. The superconducting wire is made by drawing. Thereby, the movement of the element wire 11 is restricted by the thermohardening type insulating layer 18. However, there is not present the layer 18 all over the space between the element wires 11, so that a path for a coolant to flow can be maintained.



LEGAL STATUS

[Date of request for examination]

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[Date of final disposal for application]

[Patent number]

[Date of registration]

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[Date of requesting appeal against examiner's decision of rejection]

[Date of extinction of right]

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CLAIMS

[Claim(s)]
[Claim 1] In a conductor the superconduction of the cable Inn conduit-tube mold which dedicates the stranded wire which consists of a superconductive element line of the multifilamentary wire of NbTi or Nb3 Sn in tubing made from high intensity stainless steel, and feeds and carries out forced cooling of the refrigerant into this tubing -- the superconduction characterized by having wound the insulating tape of a heat-curing mold in the direction of a long picture in the shape of a spiral, and fixing a superconductive element line to the periphery of the secondary stranded wire which twisted two or more superconductive element lines which form said stranded wire mutually -- a conductor.

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] the superconduction of the forced-cooling mold which this invention feeds a supercritical helium compulsorily and is cooled -- it is related with a conductor.
[0002]
[Description of the Prior Art] the superconduction of the forced-cooling mold cooled using single phase flow like a supercritical helium, and the forced convection of super-low hot fluid -- a conductor -- a hollow -- a conductor and a cable Inn conduit tube -- there is a conductor which combined a conductor and them. a hollow -- the actual set of many super-thin multicore superconduction lines is carried out, and it unifies with stabilization material with solder etc., and the conductor is constituted so that a hole may be made in the central part and the helium which is a refrigerant can be fed. moreover, a cable Inn conduit tube -- a conductor 8 As shown in drawing 3 , twist several super-thin multicore superconduction lines 1 of NbTi or Nb3 Sn at a time many times, and a multiplex twist is carried out at the shape of the 4 or 5th 3 or 4th 2 or 3rd secondary [in all] stranded-wire stranded-wire stranded-wire stranded wire 5 and a cable. It dedicates in the firm conduit tube (tubing) 6 which consists of SUS material, the Incoloy material, Ti material, or those alloys. It is constituted so that a refrigerant may flow to the space 7 surrounded with conduit-tube 6 walls other than a superconductive element line (U.S. Pat. No. 4,336,420 specification: Jun. 22, 1982, reference).
[0003] this kind of superconduction -- in order for a conductor to generate heat when the superconductive element line 1 in a conduit tube 6 moves within a conduit tube 6 according to electromagnetic force, and for strand temperature to prevent going up and carrying out superconduction destruction (quenching) -- the front face of the superconductive element line 1 -- solder -- thin -- coating -- the time of a stranded wire -- he carries out soldering immobilization and is trying not to move by point contact and the part which carried out line contact mutually Moreover, the motion of a strand is restrained by covering the periphery by high electric resistance material with a good heat-conduction property to the cable which bundled the stranded wire several times. Furthermore, the tube diameter was drawn through and it was made small so that it might become as small as possible about the rate (a void fraction is called below) that the refrigerant flow passage area to the cross-sectional area of the cable space in a conduit tube 6 occupies (generally before or after 35 - 40%).
[0004]
[Problem(s) to be Solved by the Invention] it mentioned above -- as -- the conventional superconduction, although solder coating of the superconductive element line in a conduit tube is carried out and a motion of a superconductive element line is restrained in a conductor Since the joint loss over a fluctuation field is large, and is this internal generation of heat and it may result in quenching for the electrical installation between superconductive element lines, When it fixed only by not combining between strands electrically but only twisting, there was a fault of becoming easy to move a strand, in the part where the diameters of bending differ, or the mighty part of electromagnetic force.
[0005] then, the conventional superconduction -- although the void fraction is made small as much as

possible in the conductor in order to prevent the ease of moving of a strand -- a conductor -- since an open circuit of the strand at the time of manufacture and a hydraulic diameter became small, pressure loss increased, as a result loss of a circulating pump became very large, and another fault, like the temperature of a refrigerant becomes high by the temperature rise by the pressure loss arose.
[0006] Although what applied adhesives, and was pasted up and fixed to each other (JP,2-297808,A) is proposed as the approach of compensating a fault which was mentioned above instead of carrying out soldering immobilization at the periphery of a superconductive element line By this approach, when pasting up strands mutually, the refrigerant passage between superconductive element lines was closed, a refrigerant would not flow, and degradation of a remarkable cooling property was caused, as a result there was a problem of producing quenching (superconduction destruction).
[0007] the superconduction which was excellent in the cooling property which secures refrigerant passage and is stable while it was made in order that this invention might solve the above-mentioned problem, and the purpose prevented the motion of the superconductive element line in a conduit tube -- it is in offering a conductor.
[0008]
[Means for Solving the Problem] In order to attain the above-mentioned purpose, this invention dedicates the stranded wire which consists of a superconductive element line of the multifilamentary wire of NbTi or Nb3 Sn in tubing made from high intensity stainless steel. In a conductor the superconduction of the cable Inn conduit-tube mold which feeds and carries out forced cooling of the refrigerant into this tubing -- It is characterized by having wound the insulating tape of a heat-curing mold in the direction of a long picture in the shape of a spiral, and fixing a superconductive element line to the periphery of the secondary stranded wire which twisted two or more superconductive element lines which form said stranded wire mutually.
[0009]
[Function] the superconduction of this invention -- since according to the conductor the motion of a superconductive element line was restrained to the minimum and the refrigerant passage between strands is secured, the outstanding stability and the outstanding cooling property are acquired.
[0010]
[Example] Hereafter, the example of this invention is explained with reference to drawing 1 .
[0011] Drawing 1 (a) is the sectional view of one example of this invention, and drawing 1 (b) is the enlarged drawing of the A section of this drawing (a). In drawing 1 , 11 is a superconductive element line, surrounds the super-thin multicore superconduction line of NbTi or Nb3Sn by stabilization material, such as Cu and aluminum, and inserts electric insulation material if needed further. As shown in drawing 2 , every three of this superconductive element line 11 are twisted, it forms the primary stranded wire 12, and three primary [further] stranded wires 12 are twisted, and form the secondary stranded wire 13. The insulating tape 14 of a heat-curing mold is wound around the periphery of this secondary stranded wire 13 in the shape of a spiral along the direction of a long picture. Thus, the stranded wire of the secondary stranded wire 13 to which the insulating tape 14 was given at the periphery is carried out many times like the conventional example shown in drawing 3 , and it constitutes the subcable 15.
[0012] the case of this example -- the subcable 15 -- 6 stranded wires -- carrying out -- a conduit tube 16 -- containing -- up to a predetermined void fraction -- dice length -- carrying out -- superconduction -- a conductor 20 is manufactured. superconduction -- the suitable process of coil manufacture after manufacture of a conductor 20 -- superconduction -- a conductor 20 is heated, the insulating tape 14 of a heat-curing mold is stiffened, and the superconductive element line 11 is fixed per secondary stranded wire. the superconduction after hardening -- a conductor 20 comes to be shown in drawing 1 (a), and what expanded the A section is shown in drawing 1 (b).
[0013] The hardening insulating layer 18 is fixing the superconductive element line 11 in the state of the primary stranded wire 12, and, thereby, is restraining the motion of the superconductive element line 11. However, since there is no hardening insulating layer 18 in all between the superconductive element lines 11, the refrigerant passage 17 is securable. Therefore, even if it forms and energizes a coil, a

motion of the superconductive element line 11 can also acquire a good cooling property while having the stability which it is almost unstable and was excellent.

[0014] In addition, although especially this example did not prescribe the volume pitch of the insulating tape of a heat-curing mold, if it is made close winding or a lap volume, by flying, since cooling surface area decreases or channeling of a current and a splitting problem arise, and performing a volume, reduction of cooling surface area will be prevented and mitigation of channeling and a splitting problem can be performed. In this case, it flies and the pitch of a volume is good to consider as 1/3 or less merit's pitch of the twist pitch of the 3rd stranded wire (33 this twist). Moreover, two secondary stranded wires are twisted, and even if it uses two or more twists, such as 4 twists, the same effectiveness as the above-mentioned example is acquired.

[0015]

[Effect of the Invention] the superconduction which was stable and was excellent in the cooling property since refrigerant passage was securable while preventing the motion of the superconductive element line in a conduit tube according to this invention as explained above -- a conductor can be offered.

[Translation done.]

* NOTICES *

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] This drawing (a) is a sectional view of one example of this invention, and this drawing (b) is an enlarged drawing of the A section of this drawing (a).
[Drawing 2] The perspective view of the one section of the secondary stranded wire of drawing 1 .
[Drawing 3] the conventional superconduction -- drawing showing the manufacture process of a conductor.
[Description of Notations]
11 -- superconductive element line, a 12--primary stranded wire, a 13--secondary stranded wire, and 14 -- the insulating tape of a heat-curing mold, a 15 -- subcable, 16 -- conduit tube, and 17 -- refrigerant passage, 18 -- hardening insulating layer, and 20 -- superconduction -- a conductor.

[Translation done.]

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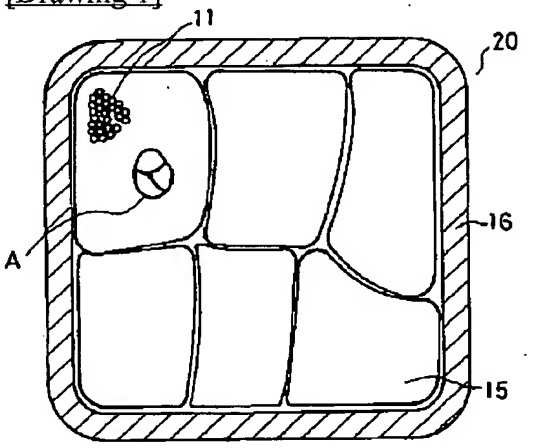
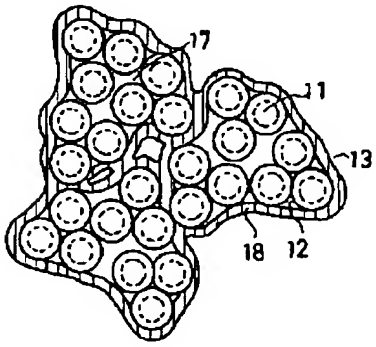
DRAWINGS

[Drawing 1]

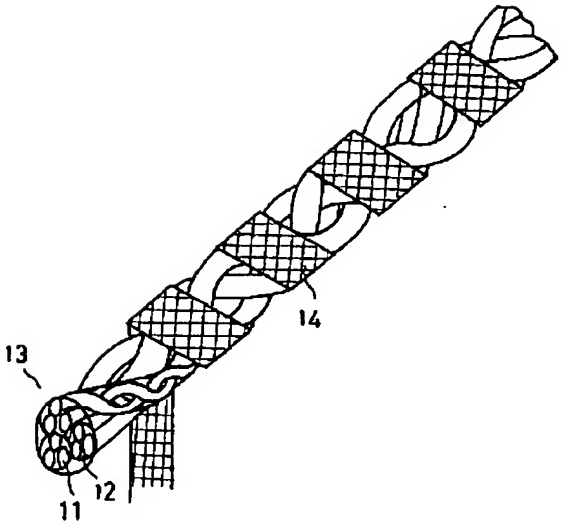


(a)

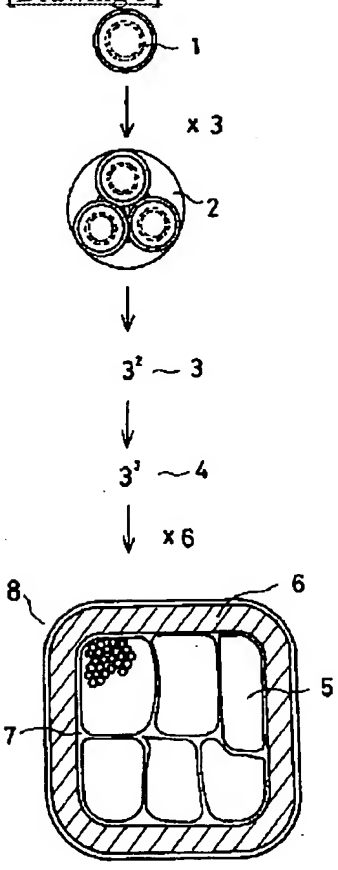


(b)

[Drawing 2]



[Drawing 3]



[Translation done.]